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(56) Documents Cited
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(54) Abstract Title

**System for remote acoustic monitoring of condition of subsea wellhead tools and downhole equipment**

(57) A method and apparatus for remotely monitoring the condition (e.g. operative state or relative position) of a subsurface tool/piece of equipment 14 by detecting acoustic emissions from the tool/equipment 14. The acoustic emissions are transmitted through an acoustic transmission medium (e.g drill string 12) to which the tool/equipment 14 is attached, and detected by a transducer in monitoring device 26 at surface level. The monitoring device 26 may be temporarily or permanently attached to the transmission medium. The acoustic emissions are either inherently generated by the use of the tool/equipment 14, or they are generated by a transducer 32 incorporated into the tool/equipment 14 that generates acoustic transmissions characteristic of the tool/equipment 14 conditions of interest. Signals from the detection transducer may be amplified, filtered, counted and the count supplied to a user display or data logger.

Fig. 1

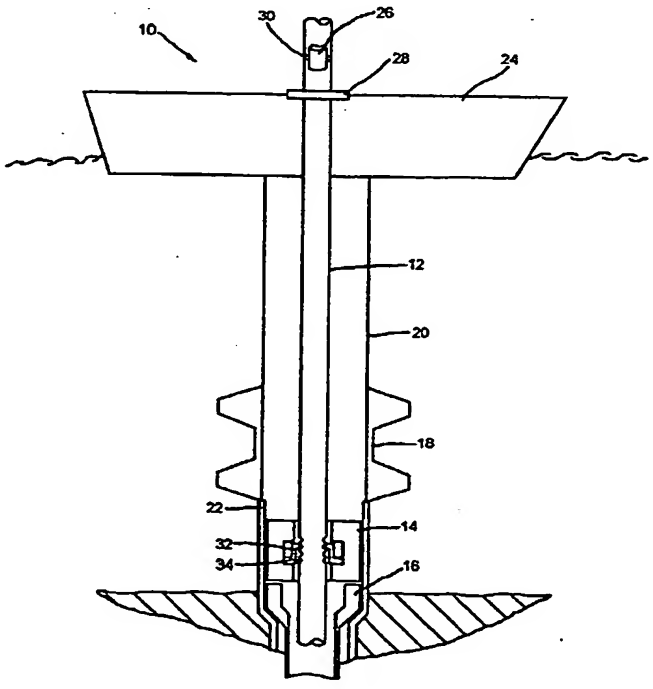


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Fig. 1

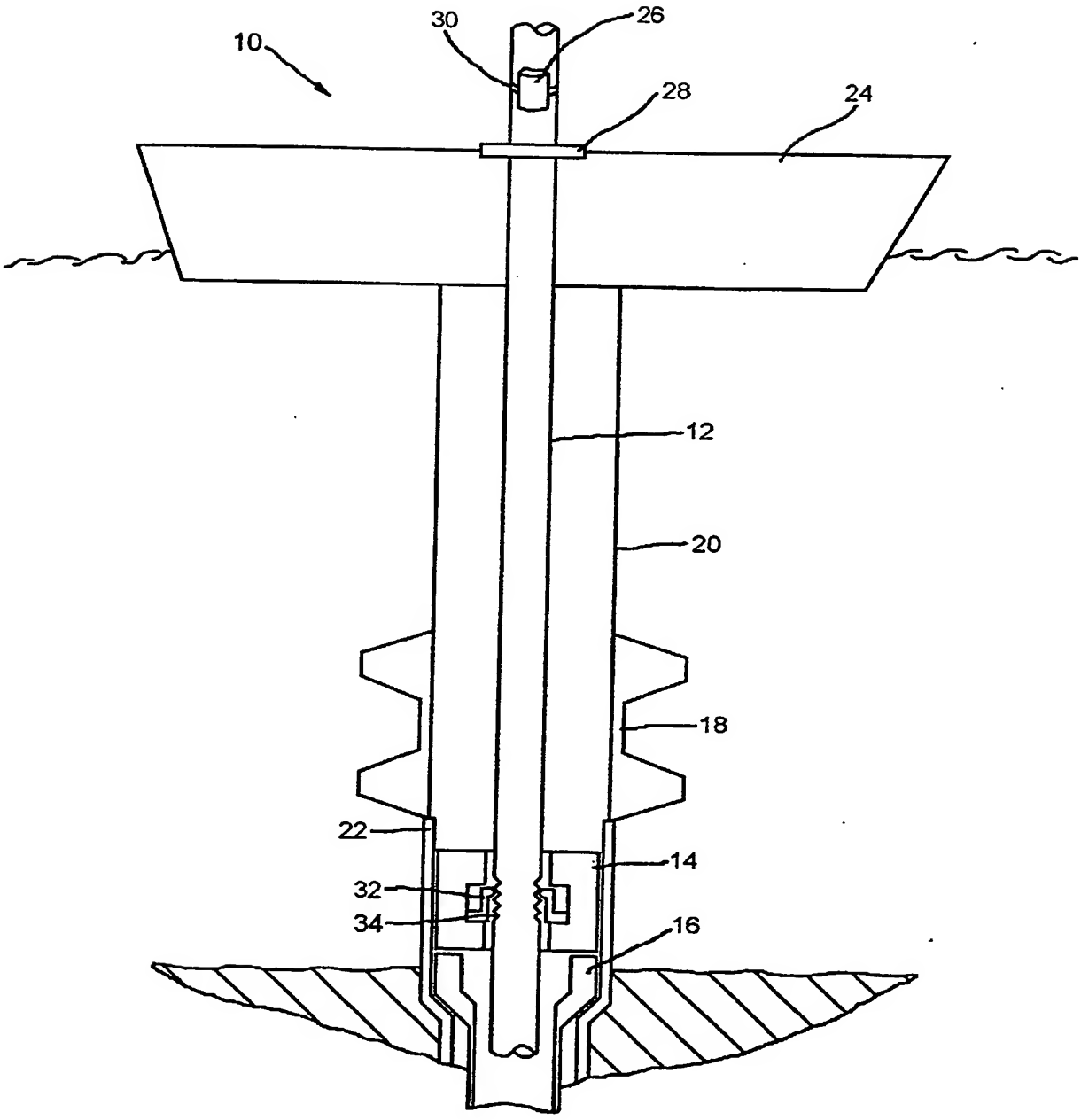


Fig. 2

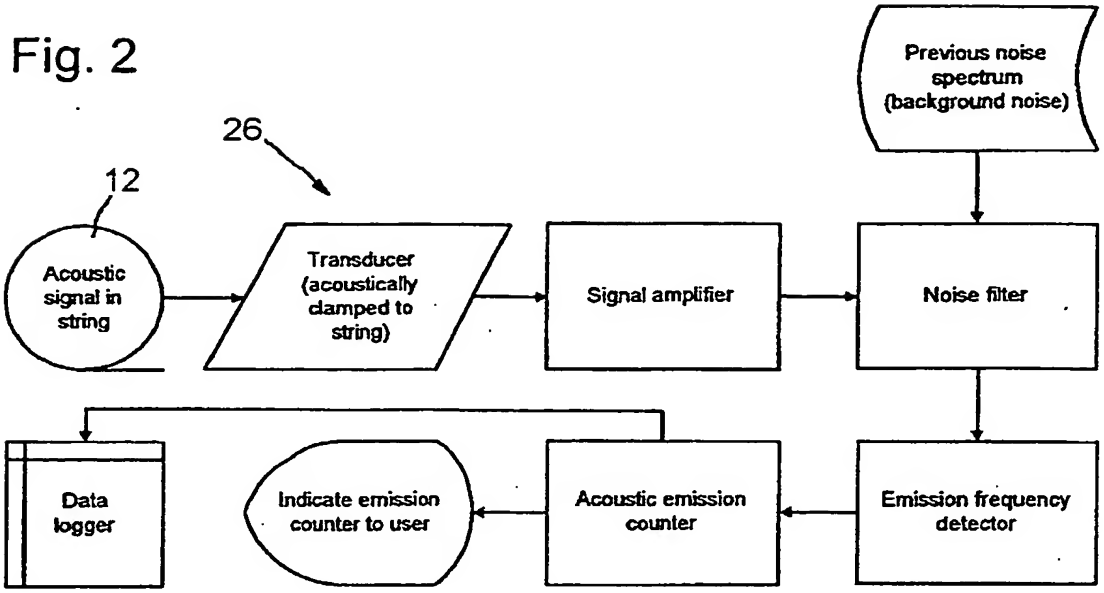



Fig. 3

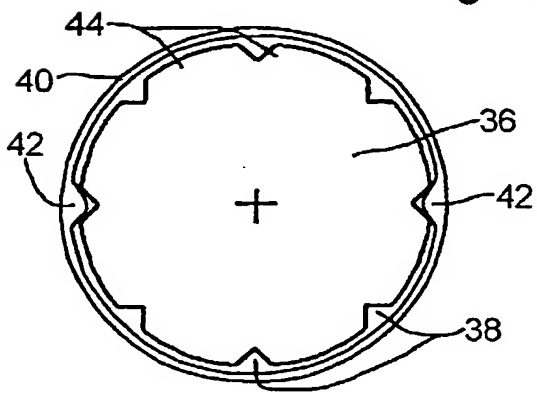



Fig. 4

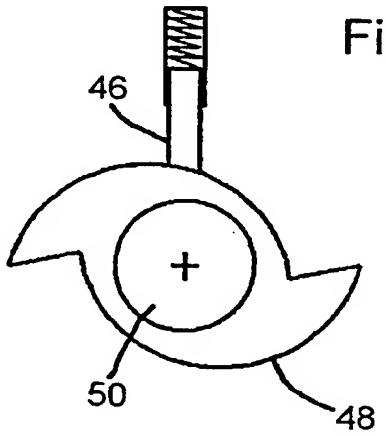
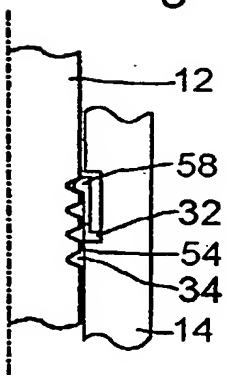



Fig. 5



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# ACOUSTIC MONITORING SYSTEM FOR SUBSEA WELLHEAD TOOLS AND DOWNHOLE EQUIPMENT

## Field of the Invention

Operation of subsurface tools and equipment used in oil and gas exploration and production, particularly when using long drill and casing/riser strings, is fraught with uncertainty. There are few methods for monitoring if a tool has been functioned sufficiently to achieve its task. The invention aims to solve the problem of monitoring tool and subsurface equipment operations by making information relating to relative tool movements (rotation, translation and position relative to a datum) easily available at the surface level.

## Background of the invention

During operation, many sub-surface tools and pieces of tubing mounted equipment (such as SCSSV's) produce a characteristic acoustic emission. For example, part of a tool may drop a short distance, striking or grating against other tool parts, producing a particular emission spectrum or signature. When those other parts are rigidly fixed to the drill string or tubing, a transmission path is provided, along which the acoustic emission may travel, for example up to the surface. There is a need to be able to monitor from a remote location, the operative state of subsurface tools and equipment. The applicants have realised that characteristic acoustic emissions may be used for this purpose.

## Summary of the Invention

Accordingly, broadly, the present invention provides a method of remotely monitoring the condition of a subsurface tool or piece of equipment, comprising the step of detecting acoustic emissions from the tool or equipment, the emissions preferably being transmitted through an acoustic transmission medium (tubing string, drill string, casing string, wireline or the like), to which the tool or equipment is attached.

The condition monitored may be the operative state of the tool/equipment (for example whether a valve is open or closed), the relative positions of tool or equipment parts, or the position of the tool/equipment relative to some specified datum.

The acoustic emissions may be of a wide range of frequencies, depending upon the emission characteristics of the tool/equipment being monitored. They may lie below, in or above the normal frequency range perceptible to the human ear. Preferably therefore, an appropriate acoustic transducer is used to detect the transmitted emissions. Preferably it is attached to the acoustic transmission medium by an acoustically conductive clamp.

In the case of emissions transmitted via a drill string, the transducer may be temporarily attached to the drill string at the drilling rig, whilst it is desired to monitor the emissions. In the case of casing strings, tubing strings, wirelines and the like that are directly accessible at the rig, the transducer may likewise be temporarily attached. For the latter, it is also possible to permanently attach the transducer, allowing it to be run in hole, closer to the source of the acoustic emissions. However, the disadvantage of this is that long signal transmission cables, that may present handling difficulties and may be prone to damage, must be used to connect the transducer to the monitoring equipment at the surface. The transducer may also be permanently attached to the transmission medium, either at the surface or downhole, in those cases where the medium is not directly accessible at the rig, for example where signal transmission cables must pass through a pressure barrier.

The monitoring method may include one or more of the following further steps:

- amplifying the signal from the transducer;
- filtering the signal from the transducer, e.g. to attenuate background noise;
- detecting characteristic emission signatures indicative of a particular state or change in state of the tool or equipment;
- counting the number of occasions on which the characteristic emission signatures occur;
- supplying such a count to a user display or a data logger.

Many tools or pieces of equipment will generate the necessary characteristic acoustic emissions as a direct result or by-product of the operation or condition that it is desired to monitor. However, that is not always the case. If required, it is possible to incorporate into the tool or equipment a motion or position to noise transducer, whose purpose is specifically to generate the acoustic emissions characteristic of the tool or device conditions of interest. In its simplest form, this can be a mechanical ratchet type device or mechanism, which emits one or more "clicks" upon relative movement between two parts. The acoustic emissions can therefore be produced by purely mechanical means either inherent to the tool/equipment, or specifically added to it, for example a ratcheting device to indicate relative rotation or translation.

The invention also extends to apparatus used for carrying out the monitoring method.

Further preferred features and advantages of the present invention are in the dependent claims and in the following description of illustrative embodiments, made with reference to the drawings.

**Brief Description of the Drawings**

Figure 1 is a schematic diagram indicating a system for remotely monitoring a subsurface tool condition using the method of the present invention;

Figure 2 is a flow diagram of processing steps applied to the acoustic emissions, and

Figures 3 – 5 schematically show examples of position or motion to noise transducers that may be used in carrying out the method of the invention.

**Description of the Preferred Embodiments**

Referring to Figure 1, a system 10 is shown that monitors the acoustic emissions travelling up a drill string 12 from a subsurface tool 14 attached to or landed in a casing hanger 16. Although a casing hanger tool is shown, the system may be used to monitor the condition of a wide variety of subsurface tools and equipment. Likewise, although as shown a drill string 12 serves as an acoustic transmission medium, other elements such as tubing or casing strings, risers, wirelines and the like can also fulfil this function. The

drill string 12 is run through a BOP 18 and riser 20, extending between a wellhead 22 and a drilling vessel 24.

An acoustic monitoring device 26 is temporarily attached to the drill string above the vessel's rotary table 28, by an acoustically conductive clamp or strap 30. The monitoring device 26 comprises an acoustic transducer and associated processing systems attached to the clamp 30 that filter and monitor the noise / acoustic emission mix in the drill string 12 and indicate when a tool driven acoustic emission has taken place. Acoustic emission data can also be logged using a data logger or similar equipment.

Key to the operation of the system is the concept that as a by-product of tool operations, tools produce (or are modified to produce) a characteristic noise (tool acoustic emissions) which for instance provide information about relative movement of parts. These acoustic emissions are noises derived from the operation of simple mechanisms such as ratchets, or impacts between other parts, arising in use of the tool. As shown, the tool 14 is modified so as to incorporate a ratchet ring 32 which co-operates with a series of ratchet grooves 34 formed in the drill string 12. As each groove in the series 34 moves past the ring 32, a characteristic acoustic emission (click or signature) is generated. This travels up the drill string 12, where it may be detected by the monitoring device 26. The monitoring device may thus be used to provide an indication of the vertical position of the drill string 12 relative to the tool 14. At its simplest, this indication could be by means of an LED or the like, which flashes every time a click is detected. A more sophisticated monitoring device 26 may include a digital display, giving a running total of the number of clicks detected. The monitoring device can also be connected to a data logger or similar recording device for the raw and / or filtered acoustic signals.

The monitoring device 26 is attached to the drill string 12 at the surface level and when it detects an acoustic emission in the drill string derived from tool movement, it indicates this to the user. Coupled with tool information relating to the number of acoustic emissions expected for correct tool operation, this enables the user to closely monitor the function of the tool. Information relating to relative tool movements (rotation, translation

and position relative to a datum) is therefore easily available at the surface level. Consider as an example a tool that must make 1 full rotation for correct operation and in which the tool is designed or modified to produce four emissions per rotation. The user simply has the drill string rotated until the device indicates it has detected four emissions.

Figure 2 shows a possible signal processing arrangement used to carry out a preferred monitoring method of the invention. Acoustic emissions are collected from the drill string via a transducer. This signal compared against the background noise spectrum and the differential (filtered) signal is fed to detection logic. The detection logic identifies transients at particular frequencies or combinations of frequencies which can be attributed to the intended acoustic emissions. These are then counted and indicated to the operator, as well as being recorded by a data logger.

Examples of position or movement to acoustic emission transducers which could be used to provide the necessary characteristic emissions in tool or equipment operations that do not produce them inherently, are shown in figures 3 –5.

Figures 3 and 4 are intended to enable monitoring of rotational movement / circular datum position and Figure 5 for axial movement / linear datum position. In Figure 3, a tool shaft 36 has a series of circumferentially spaced, axially extending grooves 38. A somewhat flexible ratchet ring 40 is positioned concentrically around the shaft, with a slight radial clearance. A pair of inwardly directed protuberances 42 can be moved between the various grooves 38 by relative rotation of the shaft 36 and ring 40, clicking past the intervening lands 44 to produce the required acoustic emissions. In Figure 4, much the same effect is obtained using a spring-loaded striker pin 46, acting against a cam 48 mounted for rotation with a tool shaft 50.

Figure 5 shows an acoustic emission generator which may be used in the system shown in Figure 1. The drill string or tool shaft 12 has a series of circumferential grooves 34 and alternating lands 54 formed on it. A ratchet ring 32 is received in a recessed groove in a vertical bore through the tool body 14. The ring 32 is partially axially split at a series of

circumferentially spaced locations, to produce a series of axially extending flexible fingers. Each finger has a thickened end 58 that can be snapped into and out of the grooves 34 and over the lands 54, to produce the desired acoustic emissions as the drill string 12 is moved axially relative to the tool 14.

Other acoustic emission generators will be readily apparent. Purely mechanical devices actuated by relative movement between parts are preferred, as they require no external connections other than the existing mechanical transmission path to the surface. However electrically powered acoustic emission generators may also be used, for example providing emissions of varying frequency or amplitude, or digitally or otherwise encoded, to represent the condition monitored. If such monitoring is required for a relatively short period, the acoustic emission generator can rely on an internal power supply.

## CLAIMS

1. A method of remotely monitoring the condition of a subsurface tool or piece of equipment, comprising the step of detecting acoustic emissions from the tool or equipment.

2. The monitoring method as defined in claim 1, in which an acoustic transducer is used to detect the emissions.

3. The monitoring method as defined in claim 2, further comprising the step of amplifying the signal from the acoustic transducer.

4. The monitoring method as defined in claim 2 or 3, further comprising the step of filtering the signal from the acoustic transducer.

5. The monitoring method as defined in claim 2, 3 or 4, further comprising the step of detecting characteristic emission signatures indicative of a particular state or change in state of the tool or equipment.

6. The monitoring method as defined in claim 5, further comprising the step of counting the number of occasions on which the characteristic emission signatures occur.

7. The monitoring method as defined in claim 6, further comprising the step of supplying said count to a user display or a data logger.

8. The monitoring method as defined in any preceding claim, wherein the detected emissions are transmitted through an acoustic transmission medium to which the tool or equipment is attached.

9. The monitoring method as defined in any of claims 2 - 7 and 8, in which the acoustic transducer is attached to the acoustic transmission medium by an acoustically conductive clamp.

10. The monitoring method as defined in any preceding claim, in which the condition monitored is the operative state of the tool/equipment, the relative positions of tool or equipment parts, or the position of the tool/equipment relative to a specified datum.

11. The monitoring method as defined in any preceding claim, comprising the further step of incorporating into the tool or equipment a motion or position to noise transducer, for generating the acoustic emissions characteristic of the tool or device conditions of interest.

12. The monitoring method as defined in claim 11, in which the motion or position to noise transducer comprises a mechanism which emits one or more "clicks" upon relative movement between two parts.

13. A method of remotely monitoring the condition of a subsurface tool or piece of equipment, substantially as described with reference to the drawings.

14. Apparatus for monitoring the condition of a subsurface tool or piece of equipment, comprising :

an acoustic transducer adapted to be coupled to an acoustic transmission medium acoustically coupled to the tool or equipment;

a detector operatively connected to the transducer to detect acoustic emissions characteristic of the tool or equipment condition to be monitored, and

a display arranged to indicate the detected emissions to a user.

15. Apparatus as defined in claim 15 in which the detector comprises a noise filter arranged to attenuate detected background noise in the transmission medium.

16. Apparatus as defined in claim 15 or 16 comprising a counter arranged to count the number of characteristic emissions detected.

17. Apparatus as defined in any of claims 14-16, comprising a motion or position to noise transducer coupled to the tool and to the transmission medium.

18. Apparatus as defined in claim 17 in which the position or motion to noise transducer comprises a ratchet mechanism.

19. Apparatus as defined in any of claims 14 – 18 comprising a data logger.

20. Apparatus for monitoring the condition of a subsurface tool or piece of equipment, substantially as described with reference to or as shown in the drawings.

21. The monitoring method as defined in any of claims 1-10 comprising the further step of incorporating into the tool or equipment an electrically powered acoustic emitter operatively arranged to generate acoustic emissions characteristic of the tool or device conditions of interest.

22. Apparatus as defined in any of claims 14-16 comprising an electrically powered acoustic emitter operatively arranged to generate acoustic emissions characteristic of the tool or device conditions of interest.

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**Application No:** GB 0110054.4 10 **Examiner:** Eleanor Thurston
**Claims searched:** 1-22 **Date of search:** 22 January 2002

# Patents Act 1977
# Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): G1G (GPDX, GPGX)

Int Cl (Ed.7): G01H 1/00. G01V1/40. E21B 47/00, 47/14, 47/16, 47/18.

Other: Online: EPODOC, WPI, PAJ.

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | GB 2179736 A | (PRAD R&D) see abstract, figures and page 1 lines 75-83 & 111-114. | 1, 2, 5, 8 & 10. |
| X | GB 1330191 A | (SOCIETE NATIONAL DES PETROLES D'AQUTAINE) see abstract, figures 1 & 7, page 2 lines 4-71 and page 3 lines 47-54. | 1-5, 8-10 & 14. |
| X | US 5289354 A | (CLAYER et al) see abstract, figure 1, column 1 lines 14-16 and column 2 lines 6-34. | 1, 2, 8-11 & 21. |
| X | US 5141061 A | (HENNEUSE) see abstract, figure 1, column 1 lines 31-48, column 2 lines 38-46 and column 4 lines 28-38. | 1-4, 8-10, 14 & 15. |

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